RESEARCH DEPARTMENT

PRELIMINARY ACOUSTIC TESTS IN THE NEW HEADQUARTERS, WALES (BAYNTON HOUSE, CARDIFF)

Technological Report No. B-089/5
UDC 534.861.1 1966/49

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for Head of Research Department

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SUMMARY

This report gives the results of a series of preliminary acoustic tests in the sound studios, cubicles and recording rooms at the BBC's new Headquarters, Wales. None of the studios was complete; no fabric covers were fitted to the acoustic treatment nor were carpets laid. It is shown that changes in building methods may have serious acoustic consequences unless a close check is maintained on the acoustic performance of the rooms as they near completion.

1. INTRODUCTION

The BBC's new Welsh Headquarters is at present under construction and a preliminary series of acoustic tests has been undertaken in order to determine with the methods of construction in use, whether or not the acoustic design of the studios will be achieved in practice, and, if not, to prescribe suitable remedial modifications to the studios. Seven visits were made to Baynton House at the request of Building Department and the Acoustics Committee. This report details the results obtained during the visits and gives the modifications recommended to Building Department. The information in this report has already been communicated to them so that the prescribed remedial treatment could be put in hand. It is considered that sufficient tests have been made to enable any necessary modifications to be carried out, and further tests will be deferred until the studios have been completed.

2. TESTS AT BAYNTON HOUSE

The results of the seven surveys undertaken are given in the following sections. The results are not given in chronological order but are arranged under studio headings.

2.1. Measurements in the Technical Block

Preliminary measurements of reverberation time were made in the editing channels W.7, W.8 and W.9, in Studio 7 and in Continuity Studio 8 and its associated cubicle.

2.1.1. Recording Studio 7 and Editing Channel W.7

The measured reverberation times for these two rooms are plotted in Fig. 1. Curve (*a*) shows the reverberation time of the studio. The designed reverberation time is approximately 0·32 secs at frequencies above 88 Hz rising to 0·52 secs at 62 Hz. From curve (*a*) it is seen that the measured reverberation time rises to 1·0 secs at 63 Hz. It is expected that the provision of a carpet, fabric covers to those absorbers which should be so equipped and the usual studio furnishings will reduce the reverberation time at frequencies above 105 Hz to the design figures. The reverberation-time/frequency characteristic of the editing channel, curve (*b*), is satisfactory.

The excess low-frequency reverberation time in the studio is a serious fault; there are well-defined double slopes in the sound decay curves and the onset of the second slope, which has a decay times of several seconds, is only 15 dB to 20 dB below the excitation level.

The well defined double decays suggested a lightly damped resonant component in the structure of the room as the cause. Examination and accelerometer measurements showed decay times of up to 5 secs at various points on the suspended ceiling structure. The same decay times were obtained, but at higher levels, when the ceiling was shock-excited. It thus seemed likely that the long second decays were due to ceiling resonances and not to undamped room modes.

The onset of the second slope occurred at a level sufficiently high to be audible and it was decided that its cause should be thoroughly investigated, so that methods of reducing the effect of the fault could be devised. It was evident, from the measurements of reverberation time made on the same occasion in W.8, W.9 and the Continuity Studio 8 and its cubicle as reported below, that this trouble was likely to occur in all areas in Baynton

House in which demountable suspended ceilings were used. On a subsequent visit to this studio, 28 of the Echostop tiles were removed and the reverberation times were then measured. These are given in Fig. 2. Corresponding sections of pulsed glides obtained with and without the tiles are given in Fig. 3, from which it can be seen that removal of 28 of the ceiling tiles depressed the onset of the second slope by 10 dB to 15 dB. In this condition, the second slopes were less obvious except when listening with the ear close to the ceiling frame. The second slope could be further depressed by grasping the framework and applying weight.

A vibration generator was used to drive the framework and the excitation frequency was varied from 40 Hz up to 1 kHz. The output of an accelerometer which was attached to the framework showed that there was a series of modes of vibration having Q-factors in excess of 25.

The problem was discussed with the acoustic architects of Building Department, and it was decided on cost grounds that the ceiling should be stiffened in stages until satisfactory. The simplest possible stiffening was to increase greatly the number of vertical hangers carrying the metal channels into which the tiles were fitted. At the next visit it was found that only two additional hangers had been fitted instead of the recommended twenty, and Fig. 2 shows that the chief effect was to shift the modes of vibration to higher frequencies. It produced a severe peak, centred at 355 Hz, in the reverberation-time frequency-characteristic.

It was then found that the feet of the hangers were all wrongly cut, see Fig. 4, so that the stiffness of the angle iron from which the channelling is suspended was greatly reduced. It was decided therefore, that diagonal bracing should be installed as indicated in Fig. 5. It will be seen from Fig. 2 that the effect of this bracing was to reduce the reverberation time to 0·45 secs at frequencies above 180 Hz. A noticeable effect of this modification was that the onset of the second slopes had been depressed to a point about 30 dB below the excitation level. The long second decays at low frequencies were still just audible when excited acoustically by warbled tone, but it was thought that the studio would be satisfactory for speech.

On a later visit further reverberation times were measured from the slope of the first 30 dB of the decays with the tiles in place and then with 28 of the tiles removed. A temporary carpet was laid to obtain a realistic reverberation time at higher frequencies. Fig. 6 shows the results, from which it can be seen that, with the additional stiffening installed, the removal of 28 of the ceiling tiles does not now greatly affect the reverberation times. Critical listening tests were carried out on speech, and it was agreed that, except with one speaker who was suffering from a cold, colourations due to the second slopes of the decay curves were not noticeable.

This studio was investigated in such detail because it suffered from the defects which are typical of those that occur in other areas in Baynton House fitted with suspended demountable ceilings. It is to be expected that the remedial treatment that has proved successful in this studio will be successful if applied to the ceiling frameworks of the other studios.

2.1.2. Continuity Studio 8 and its Cubicle

The reverberation-time frequency-characteristics for these two rooms are shown in Fig. 7. The rooms were incomplete and no carpets were fitted. It is probable that fitted carpets, furniture and furnishings will reduce the high frequency reverberation times to the design figure of 0·32 secs at frequencies above 500 Hz. The excessive reverberation times at frequencies below 180 Hz are caused by the suspended ceilings. The long second slopes start some 25 dB below the excitation level and will probably be noticeable on music; speech quality may be satisfactory.

2.1.3. Editing Channels W.8 and W.9

The reverberation times for these two rooms are given in Fig. 8, from which we see that the low frequency reverberation times are again excessive due to second slopes in the decay curves. Provision of carpets, furniture and furnishings should reduce the reverberation times at the higher frequencies to the designed figure.

3. MEASUREMENTS IN THE STUDIO BLOCK

Measurements of reverberation times, sound insulation and background noise levels were made in Studios 2, 3, 4, 5 and 6, and a thorough investigation was made into the behaviour of the light angle-iron framework designed to support the sound absorbing units in Studio 1.

3.1. Studio 1

In this studio the acoustic treatment is to be mounted on an angle iron framework which protrudes 0·61 m from the wall so that the unsightly wiring and ventilation trunking may be mounted at the rear of the absorbers. The framework consists of vertical strips of angle-iron about 0·68 m apart which are fixed to the horizontal concrete-clad steel joists spaced at 3·6 m centres in the walls. Short pieces of angle-iron are fixed at right angles to the above vertical members and in turn carry a framework of angle-iron parallel to the wall with wooden battens bolted to them to form a 1·2 m by 0·6 m framework to which the absorbing units are screwed.

The defects in Studio 7 described above suggested that this type of structure would be expected to vibrate and re-radiate low frequency sound. When all the absorbers are installed, the structure should be very stiff in the vertical and lateral directions, but will be highly compliant in the direction normal to the wall. It is vibration in this direction that will most effectively radiate sound into a room.

At the request of Building Department, measurements were carried out on a small section of the framework which had been completed for the purpose and loaded with typical absorbing units. The framework was driven by a vibration generator, an accelerometer was attached to points on the framework and the output of the accelerometer was applied to the normal reverberation time measuring equipment. The drive and pick-up were both in the direction normal to the wall and the decay times obtained are plotted in Fig. 9 which shows that some decay times were of the order of 4 secs. In order to measure the decay times it was necessary to stop a diesel engine working on the site because the airborne sound from the engine excited the framework into vibrations of sufficient amplitude to interfere with the reading of the decays. This suggests strongly that the airborne sound produced by an orchestra performing in the studio would be capable of exciting the framework and that the 4 secs decay times of the structure would then produce colourations of the sound. It was decided to stiffen the structure in a series of stages. The first stage, which was not expected to be particularly effective was to install simple diagonal bracing. This increased the vertical stiffness appreciably but provided little increase in stiffness of the structure in the direction normal to the wall. Fig. 9 curve (*b*) shows the long decay times obtained. Wooden "V" braces were then applied to the framework, the apex of the "V" being fixed to the outer plane of the framework and the feet of the "V", 1·21 m apart, being attached to the vertical angle iron at the surface of the wall. It was further specified that at the points of attachment of the feet of the "V" bracing to the angle iron, the angle iron itself should be bolted back to the wall. Thus the framework would be fixed to the wall at 1·2 m centres instead of at 3·6 m centres. Measurements of decay times of the framework were again made and the results are shown as curve (*c*), Fig. 9, from which it is evident that the "V" bracing plus the extra fixing bolts successfully reduced the decay times of the loaded framework to values much lower than 1·6 secs, the designed reverberation time for the studio. Providing that the wooden "V" braces and extra fixing bolts are installed, as specified to Building Department, it is not anticipated that this method of mounting the acoustic treatment will produce undesirable effects.

Two further matters requiring urgent attention were noted in this studio:

1. The studio structure consists of concrete-clad steel joists spaced 3·6 m apart. The inner section of the wall is of brick and mortar infill resting on soft board on the joists. The top layer of the bricks and the underside of the concrete-clad steel joists are again isolated by soft board. There are gaps of up to 25 mm between the bricks and soft board and unless these gaps are well packed, the sound insulation of the walls will be reduced.

2. Inspection of the wall cavities, where possible, showed that many of the special isolating wall ties had large accumulations of mortar completely bridging the rubber. In two places cavity boards were visible jammed between the two sections of the walls. If this is typical, then it is to be expected that the insulation between the two skins will be severely degraded. Building Department is taking steps to ensure that this bridging of the compliant ties is eliminated.

3.2. Studio 2

Measurements of reverberation times and of background noise levels were made in Studio 2, its recording room and its control cubicle. Fig. 10, curves (*a*), (*b*) and (*c*) respectively show the reverberation times in the three areas. No carpets were fitted and the fabric covers to the absorbers were not in place. Pronounced rattles and rings of the lighting fittings in the studio obscured the last 20 dB of the decay curves at frequencies of 63 Hz and 88 Hz and the quoted reverberation time at these frequencies was obtained from the first 30 dB of the decays.

In this studio all absorbers up to the level of the top of the observation windows are to be covered with fabric; above this level the absorbers have no fabric covers. The upper parts of the studio walls are covered with bonded absorbers together with some wide-band absorbers so arranged that bonded absorbers face each other and wide-band absorbers face each other. This arrangement is conducive to the maximum production of flutters at heights in excess of 2·45 m, but since the sound sources will be well below this height it is probable that flutters will not be much in evidence. It is, however, expected that the reverberation times of the studio will be different in the regions below and above 2·45 m. At microphone positions above 2·45 m it is expected that the low-frequency reverberation times will be lower and the high-frequency reverberation times higher than at levels below 2·45 m. This effect was detectable even in the absence of the fabric covering which is to line the walls up to the height of 2·45 m and will be more pronounced when the fabric covers and carpet are installed. It is difficult to forecast the subjective effects, which may not necessarily be unpleasant, and listening tests will be awaited with interest.

The reverberation times measured in the recording room and the control cubicle both exhibit the low frequency rise typical of small studios at Baynton House. The second slopes in the decay curves due to the suspended ceilings start 25 dB to 30 dB below the excitation level. Installation of studio furniture, equipment, carpet and fabric covers should reduce the high frequency reverberation times adequately.

Measurements of sound insulation were made from the studio to the recording room, from the studio to the control cubicle and from the studio to the narrator's studio. The measurements of sound insulation in the recording room were limited to frequencies below 250 Hz by the excessive ventilation noise. The curves are given in Fig. 11, together with the criterion curves. The insulations are adequate from the studio to the narrator's studio and from the studio to the control cubicle. The insulation from the recording room to the studio is likely to be insufficient since the programme will normally be monitored from the replay heads of recording machines and will therefore be delayed. For such cases it has been found that the insulation should be equivalent to that required between a studio and a cubicle or editing room monitoring a different programme. Large holes in the walls above suspended ceiling level between the recording room and the control cubicle prevented meaningful measurements of insulation between these areas. The existence of these holes and similar holes in other areas was notified to Building Department for their attention.

Provisional background noise levels are given in Fig. 12 for the studio and in Fig. 13 for the control cubicle and the recording room. No inlet and extract grilles were fitted in the studio. The measurements in the control cubicle and the recording room were obtained with a peak reading instrument and the curves have been lowered by 5 dB to give an equivalent r.m.s. value. As can be seen from Fig. 12 even in the absence of grilles the noise level is excessive in the 500 Hz region. The measurements must be considered provisional because the ventilation system is not yet balanced and some of the inlet and extract grilles are missing.

3.3. Studio 3 Areas Including the Narrator's Studio Which is Shared With Studio 2

Measurements of reverberation times and background noise levels and sound insulation were made in these areas.

The reverberation curves for the Narrator's Studio (*a*), Studio 3 (*b*), its control cubicle (*c*) and its recording room (*d*) are shown in Fig. 14. The decay curves again exhibit second slopes starting about 25 dB below the excitation level. The reverberation curves shown ignore the effects of the second slopes of the readings and are confined to the first 25 dB to 30 dB of the decays. No carpets or fabric covers were fitted and provision of these together with the usual furniture should reduce the high frequency reverberation times to acceptable values.

It was useless to attempt to measure sound insulation between the narrator's studio and Studio 3 or between the control cubicle and recording room as there were large unblocked holes in the walls above the level of the suspended ceilings. Fig. 15 curves (*a*) and (*b*) show the sound insulation measured from Studio 3 to its control cubicle, and from Studio 3 to its recording room respectively, together with the appropriate criterion curves. The insulation from the studio to its control cubicle is satisfactory, but that from studio to recording room is, for the reasons given in 3.2. for another suite, probably insufficient.

Provisional noise levels from Studio 3 and the narrator's studio are given in Fig. 16. No inlet or extract grilles were fitted and the noise levels in Studio 3 are excessive. In the absence of grilles, the noise level in the narrator's studio is just satisfactory. Provisional noise levels in the control cubicle and recording rooms are given in Fig. 17. The grilles are fitted in these areas and, as is typical of the type of grilles fitted in the studio block, excessive noise is produced by mechanical vibration of the grille vanes, showing peaks in the 350 Hz region. The figures quoted have been converted to r.m.s. by subtraction of 5 dB. It is understood that the ventilating contractors are making modifications.

3.4. Studios 4, 5, 6 and Their Associated Cubicles

Reverberation times, sound insulations and background noise levels were measured in these areas. From Figs. 18 and 19, it will be seen that these rooms all have high reverberation times at low frequencies. The second decays start 20 to 30 dB below the excitation level and may well make their presence evident on speech. Carpets, fabric covers to the absorbers and studio furniture should reduce the high frequency reverberation time to the design figure.

The noise levels measured in the three studios and their control cubicles are given in Figs. 20, 21 and 22. The prominent peaks in the noise curves are due to mechanical vibrations of the vanes of the extract grilles which are excited by the turbulent airflow past the peak of the "Y"-shaped vanes. Even in rooms in which the grilles do not ring, for example cubicle 4, the noise levels still exceed the criterion curves. The ventilation system is not yet balanced but there appears to be a widespread noise

component centred at about 500 Hz in all of these areas.

Sound insulations were measured between adjacent pairs of rooms and the measured results are shown in Figs. 23 and 24. The high level of ventilation noise masks the sound in the receiving rooms and it was thus not possible to measure the insulation at frequencies above 250 Hz from Studio 6 to Cubicle 5 or from Studio 5 to Cubicle 4. The insulation between Studios 4, 5 and 6 and other cubicles is adequate.

4. SUMMARY OF FINDINGS

4.1. Studio 1

The angle iron framework designed to support the acoustic treatment has been shown to be a source of excessive reverberation times. A section of the framework has been stiffened by the addition of "V" braces and by trebling the number of pins fixing the framework to the walls. Measurements have shown that the additional bracing and fixing pins as specified should prevent low frequency colourations in the completed studio. It will be necessary to ensure that the gaps between the concrete-clad steel joists and the brick panels are well packed and that the compliant wall ties are not bridged by mortar.

4.2. Reverberation Times

The smaller studios at Baynton House and their associated cubicles and recording rooms are provided with demountable plaster tile ceilings carried on a highly compliant metal framework. The low-frequency reverberation times in these rooms are in general excessive and the reason for this has been traced to high-"Q" modes of vibration of the ceiling structure causing second slopes in the decay curves. Experiments in Studio 7 have indicated that additional bracing of the steel framework is effective in depressing the start of the second slopes from levels 15 to 20 dB below excitation level to 30 dB below excitation level. Critical listening tests on speech under this condition indicated that the studios with stiffened ceilings will give satisfactory speech quality.

4.3. Sound Insulation

The presence of large holes in the walls above the level of the suspended ceilings has prevented the measurement of sound insulations in some areas and in other areas high levels of ventilation noise produced by vibrations of the grilles have also prevented measurements.

Where measurements could be made, the sound insulation between the studios and their control cubicles and from the studios to the narrator's studio were adequate, but the sound insulations from the studios to the recording rooms may require improvement. It should be emphasized that the requirement for this condition, that is from a studio to its recording room, is that specified for studios from control cubicles carrying different programmes, since in the recording room the replayed, and therefore delayed, programme will be monitored.

4.4. Noise Levels

In general, the background noise in all areas except the narrator's studio is excessive. Many of the extract grilles emit pure tones from their "Y"-shaped vanes which are forced into oscillation by the turbulent airflow past their tips. In all studios, even those which have no grilles fitted, the noise spectrum shows a broad hump in the 500 Hz region. The contractors state that the ventilation plant is not yet balanced and that they are taking measures to damp out the oscillations of the vanes of the grilles.

5. CONCLUSIONS

The tests at Baynton House which have been undertaken with the full agreement and co-operation of Building Department, were made during the course of building operations and before any area was completed. The tests have shown up certain defects in sound insulation, acoustics, and background noise associated with the new methods of construction. These defects, together with recommendations for remedial treatment are summarised in Section 4 above.

Had this series of preliminary tests not been undertaken and had the faults discussed above not been discovered at this stage of the construction, many of the studios would have proved, on completion, to be unsatisfactory. This report therefore underlines the necessity for preliminary acoustic tests by experienced engineers during the construction of all new studios.

It is not proposed to carry out more tests at Baynton House until the studios have been completed and furnished, unless more information on certain specific points should be urgently required by Building Department.

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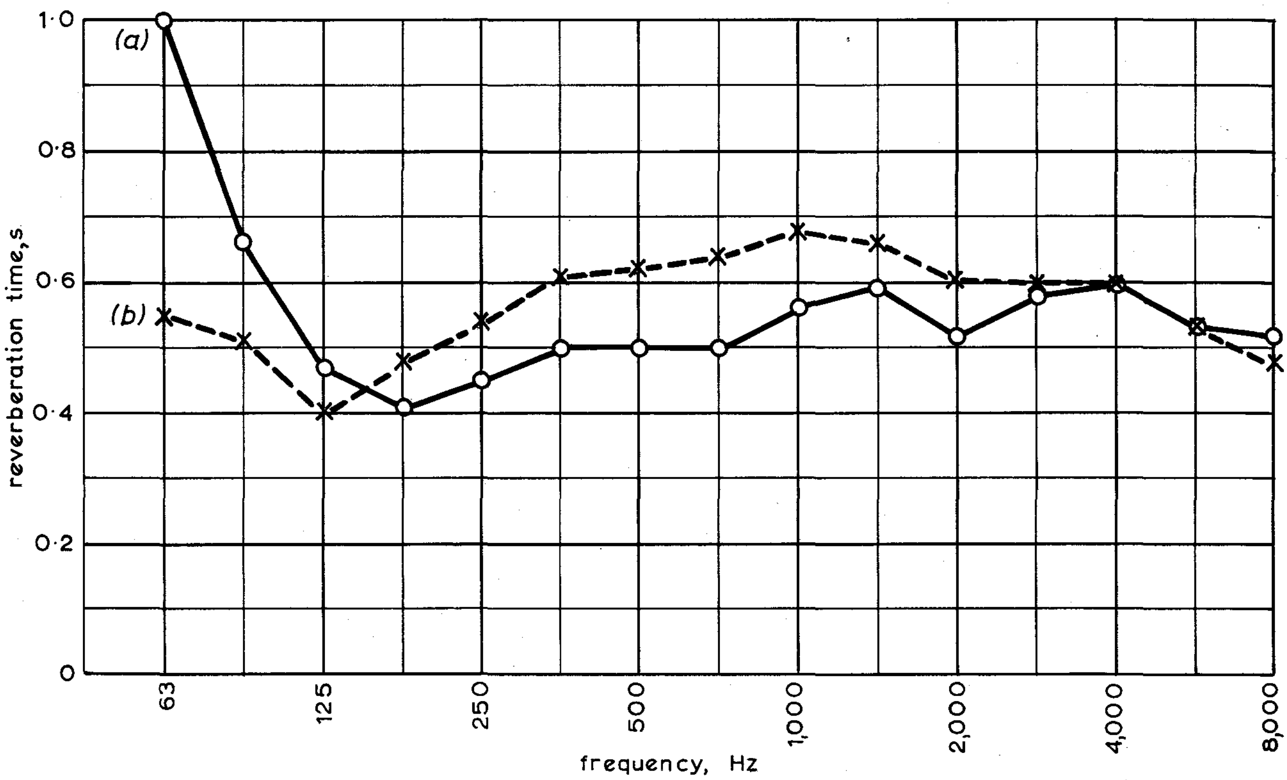


Fig. 1 Reverberation times in Studio 7 Suite

(a) Recording Studio 7. *(b)* Editing Channel W7.

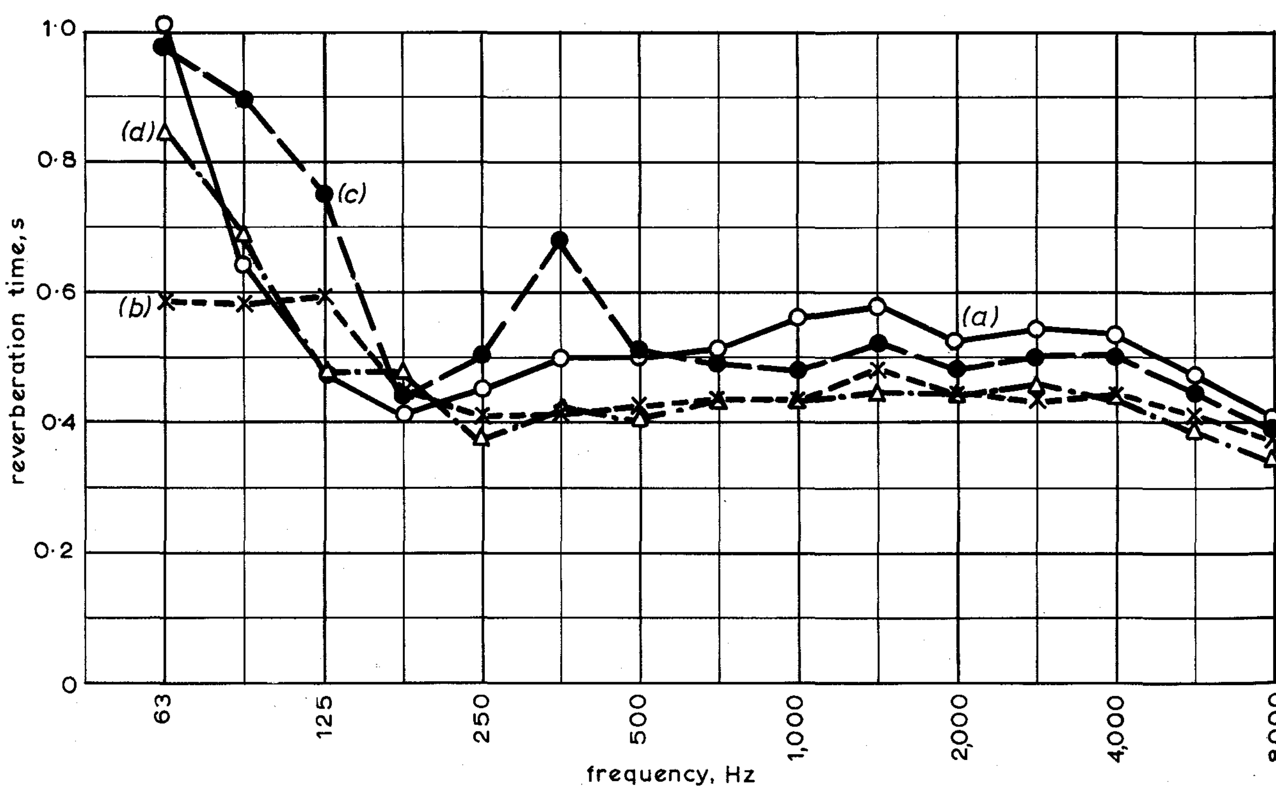


Fig. 2 Reverberation times in Studio 7.

(a) Original state, all tiles in place. *(b)* After removal of 28 tiles.
(c) All tiles in place, 2 extra hangers installed. *(d)* Final state after stiffening.

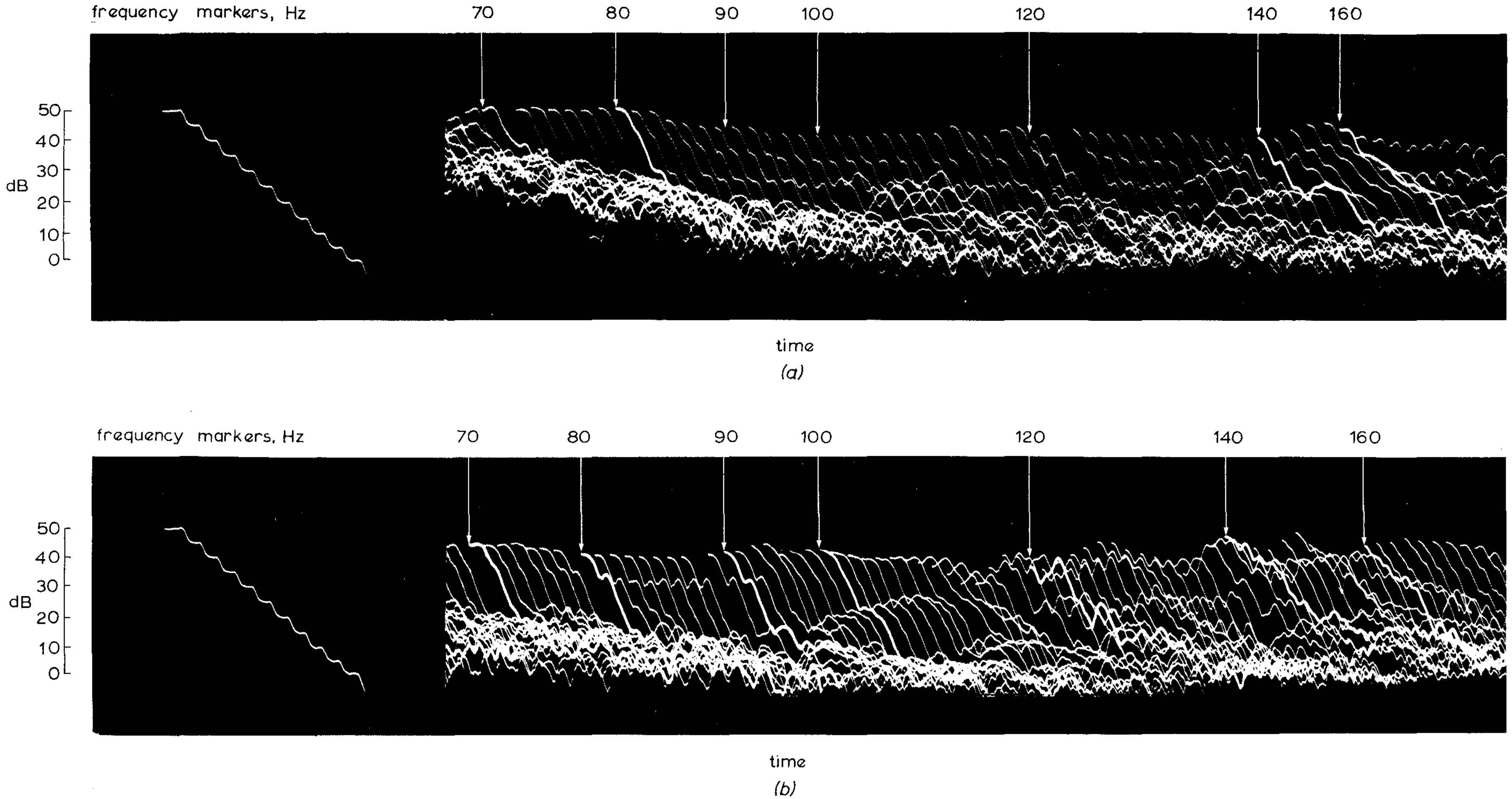
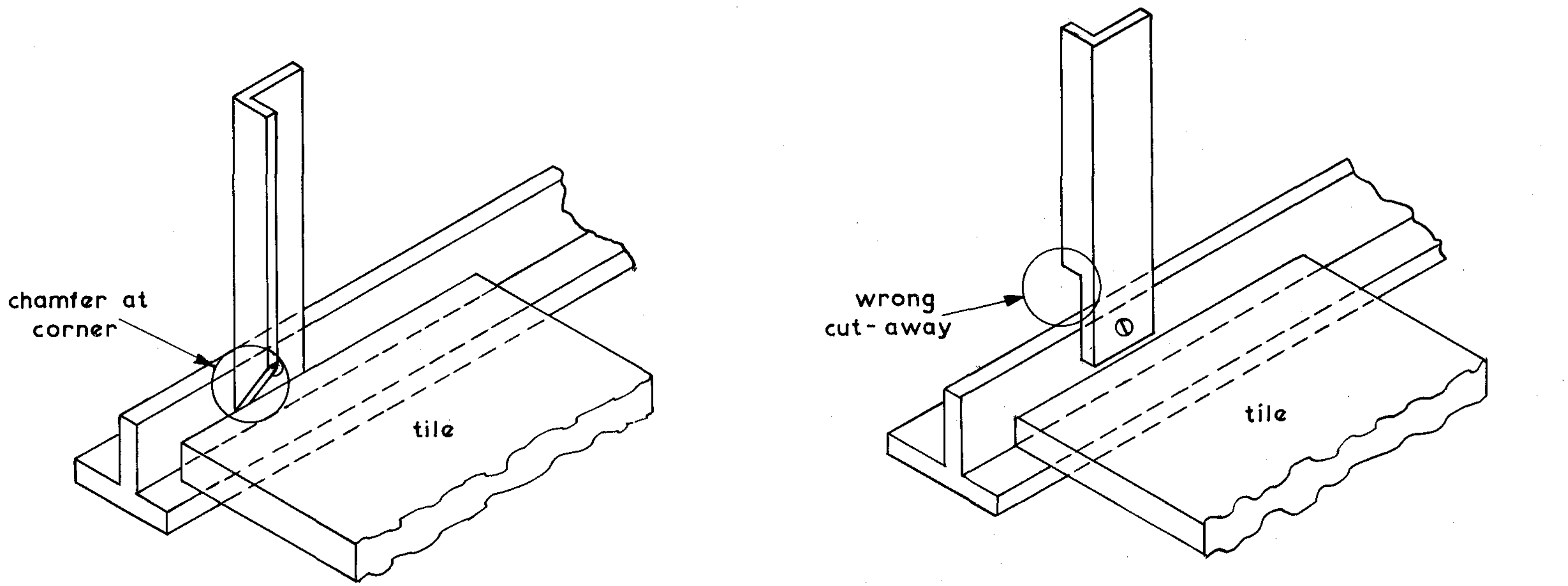


Fig. 3 Pulsed glides obtained in Studio 7

(a) All tiles in place (b) 28 tiles removed.



(a) Manufacturer's detail. (b) As installed.

Fig. 4 Details of ceiling hangers
in Studio 7.

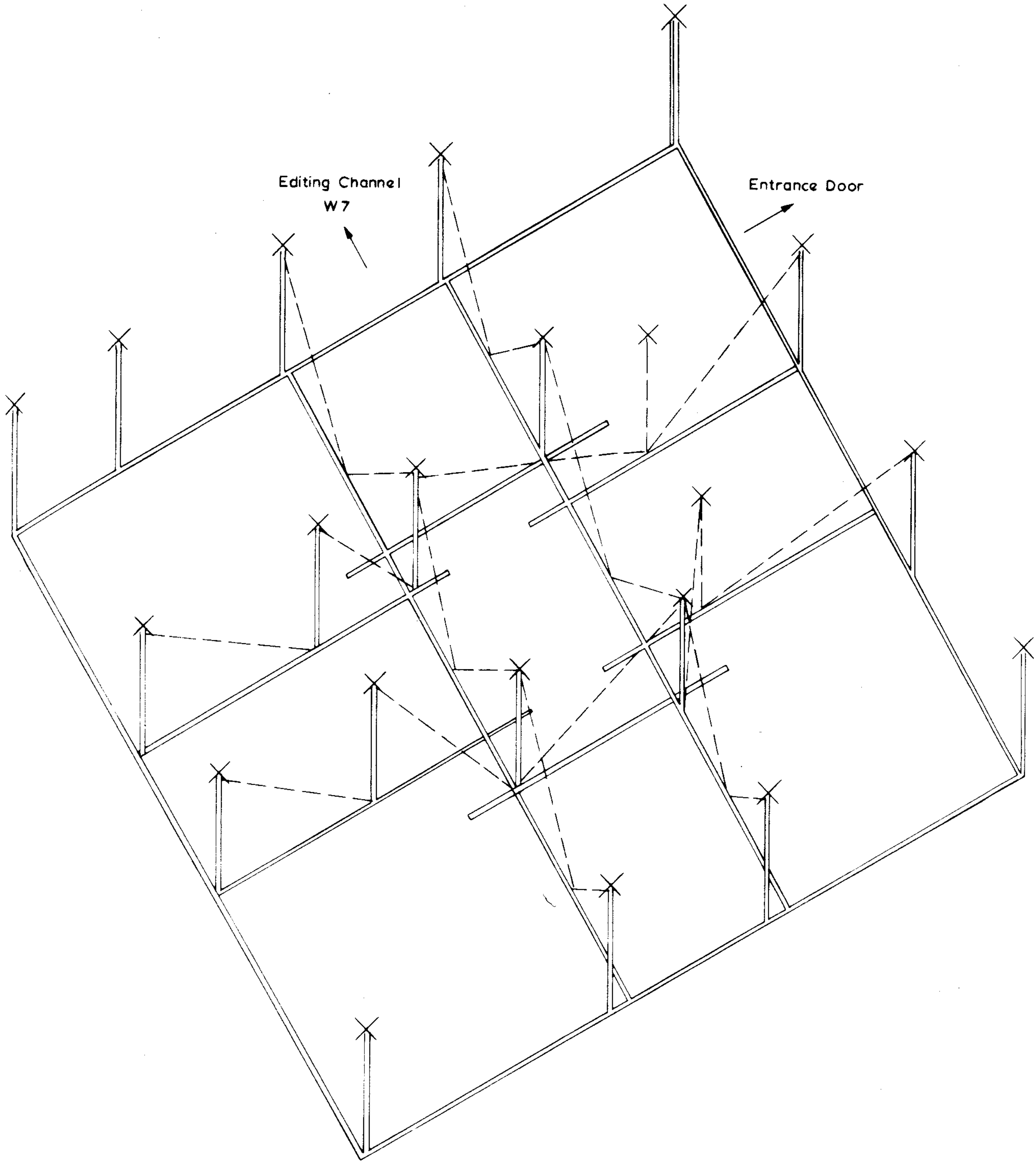


Fig. 5 Axonometric projection from above showing ceiling plan of Studio 7.
Additional braces shown dotted.

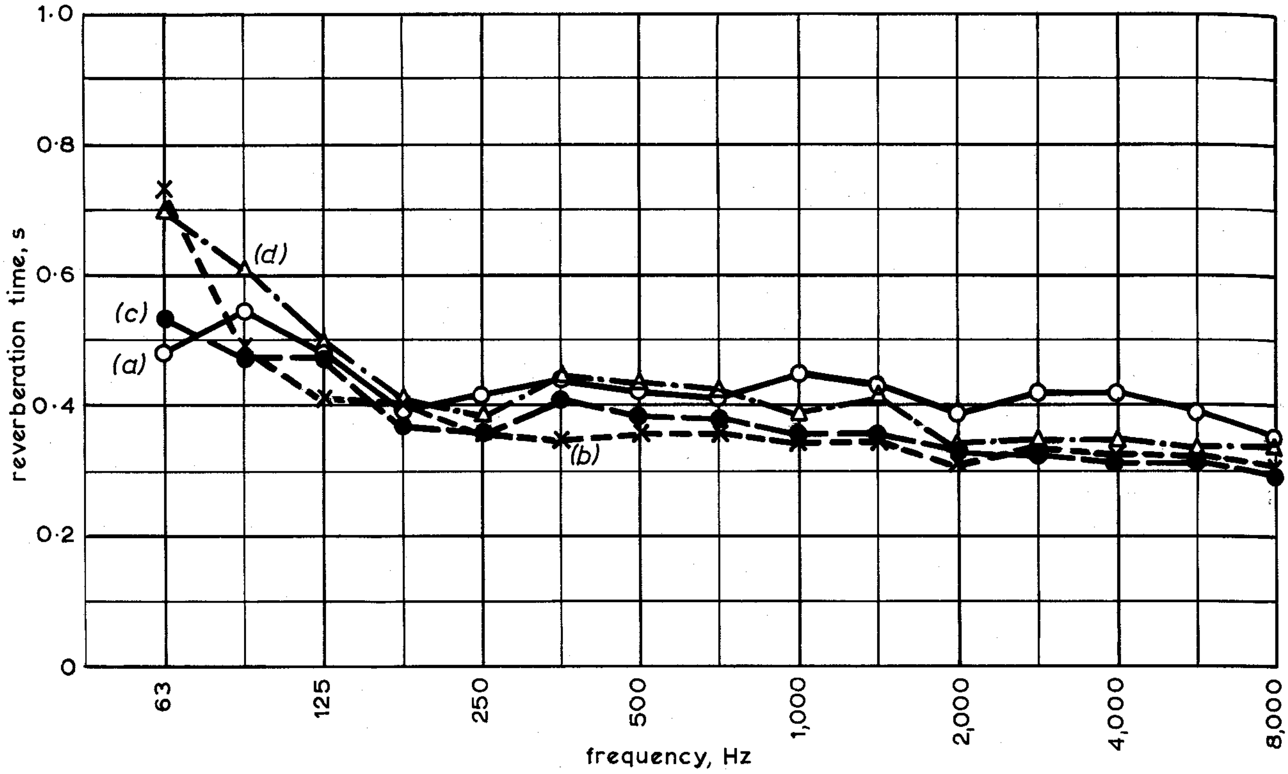


Fig. 6 Reverberation times in Studio 7.

(a)	With 5 people + 2 rolls of underfelt.	All tiles in place
(b)	With 3 people + temporary carpet.	
(c)	With 6 people + temporary carpet.	6 tiles removed
(d)	With temporary carpet.	28 tiles removed

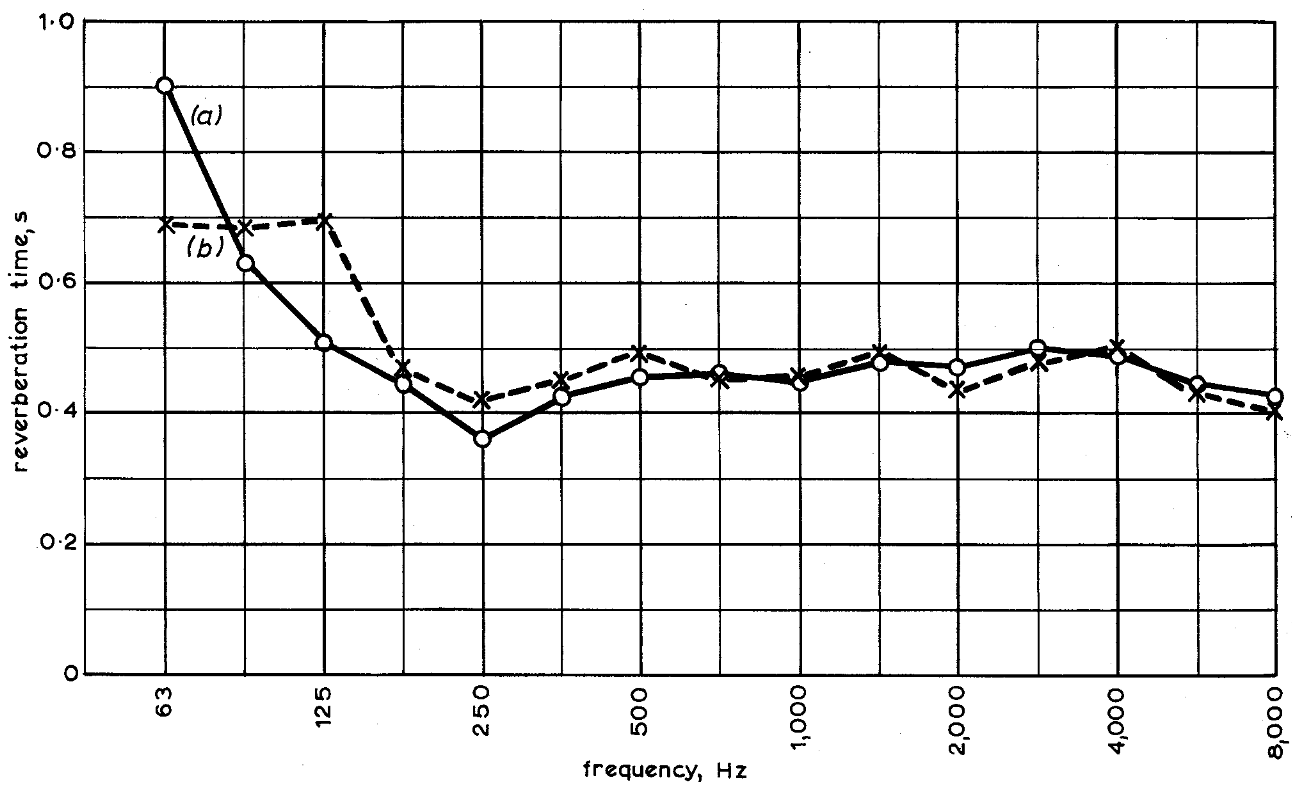


Fig. 7 Reverberation times in Studio 8 Suite

(a) Continuity Cubicle 8. (b) Continuity Studio 8.

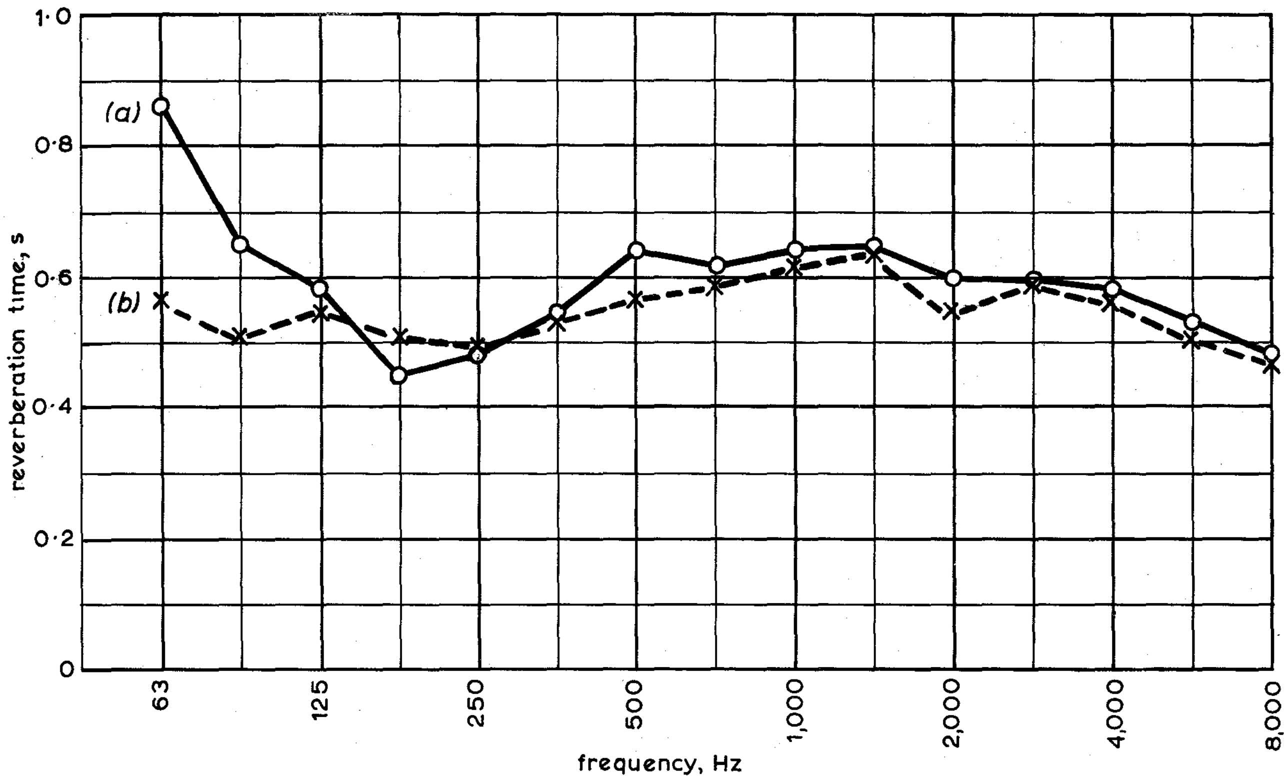


Fig. 8 Reverberation times in Channels W8 and W9.

(a) Channel W8. *(b)* Channel W9.

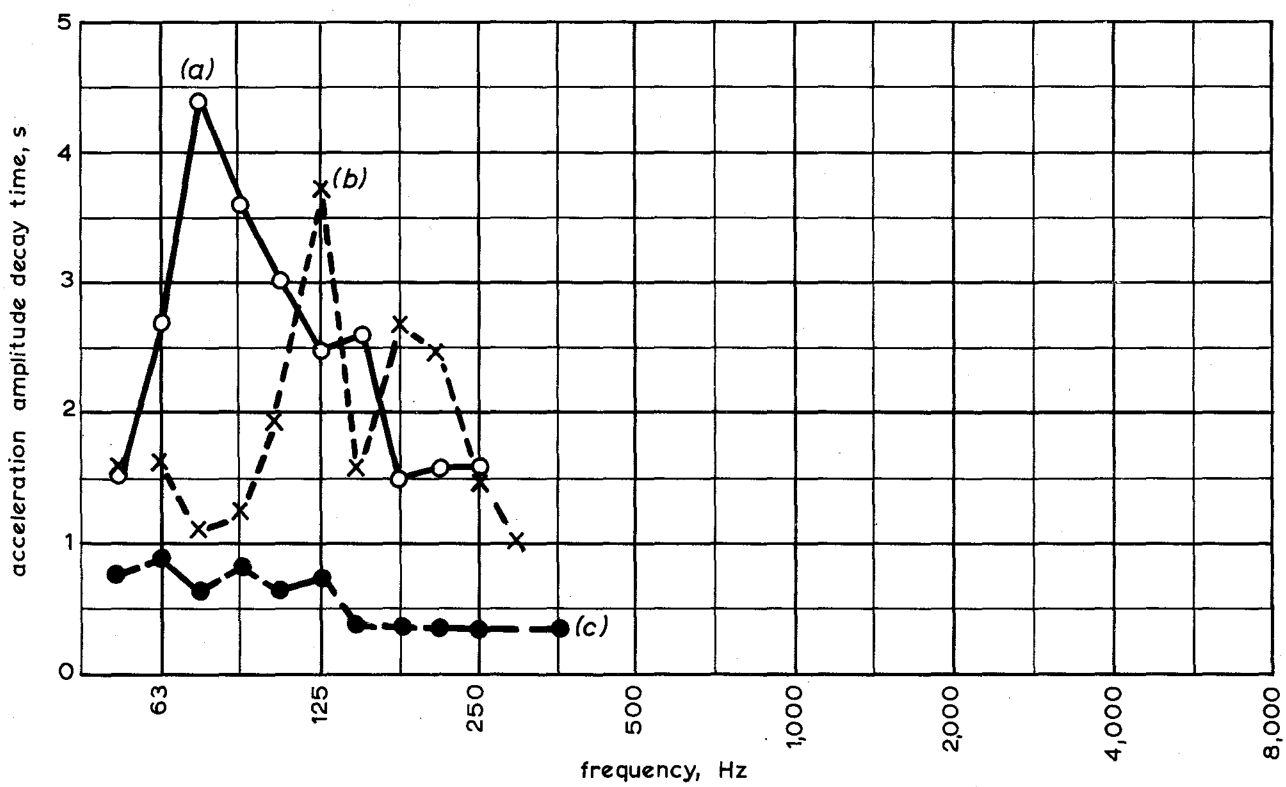


Fig. 9 Decay times of framework in Studio 1.
(Measured perpendicular to the wall).

(a) Before stiffening. *(b)* With simple stiffening.

(c) With "V" stiffening and additional fixing pins.

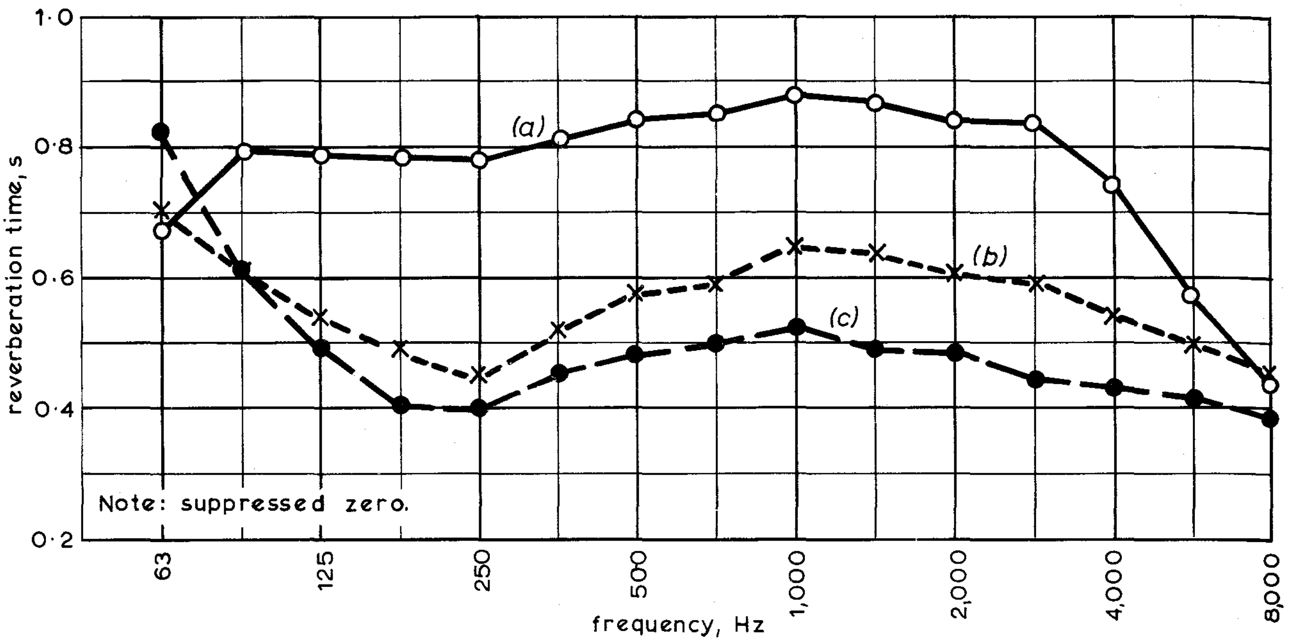


Fig. 10 Reverberation times in Studio 2 Suite

(a) Studio 2. *(b)* Control Cubicle of Studio 2. *(c)* Recording Room.

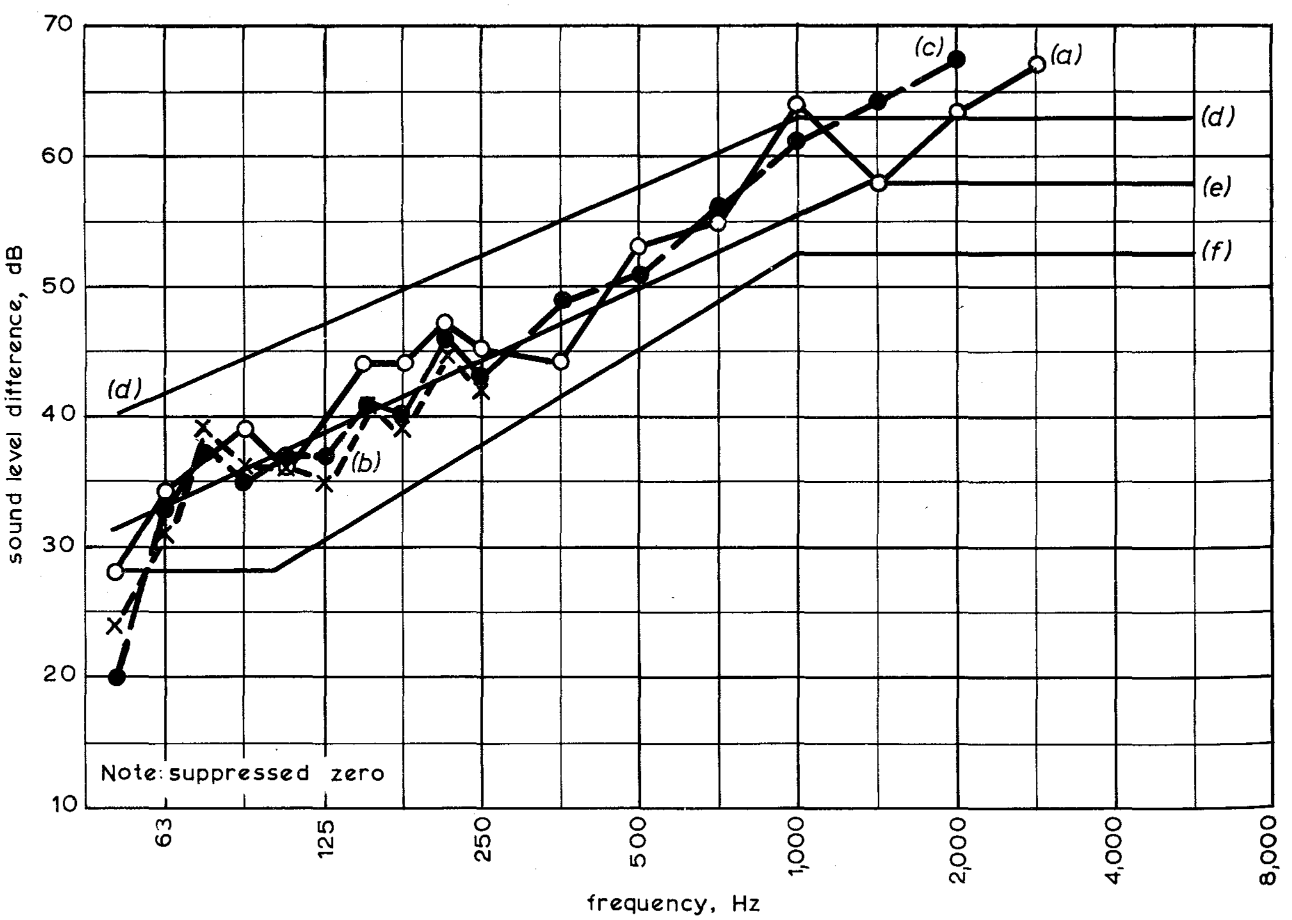


Fig. 11 Sound insulation measurements in Studio 2 Suite

(a) Studio 2 to Control Cubicle *(b)* Studio to Recording Room
(c) Studio 2 to Narrator's Studio. *(d)* Criterion, Studio to Recording Room.
(e) Criterion, Studio to Studio. *(f)* Criterion, Studio to own Cubicle.

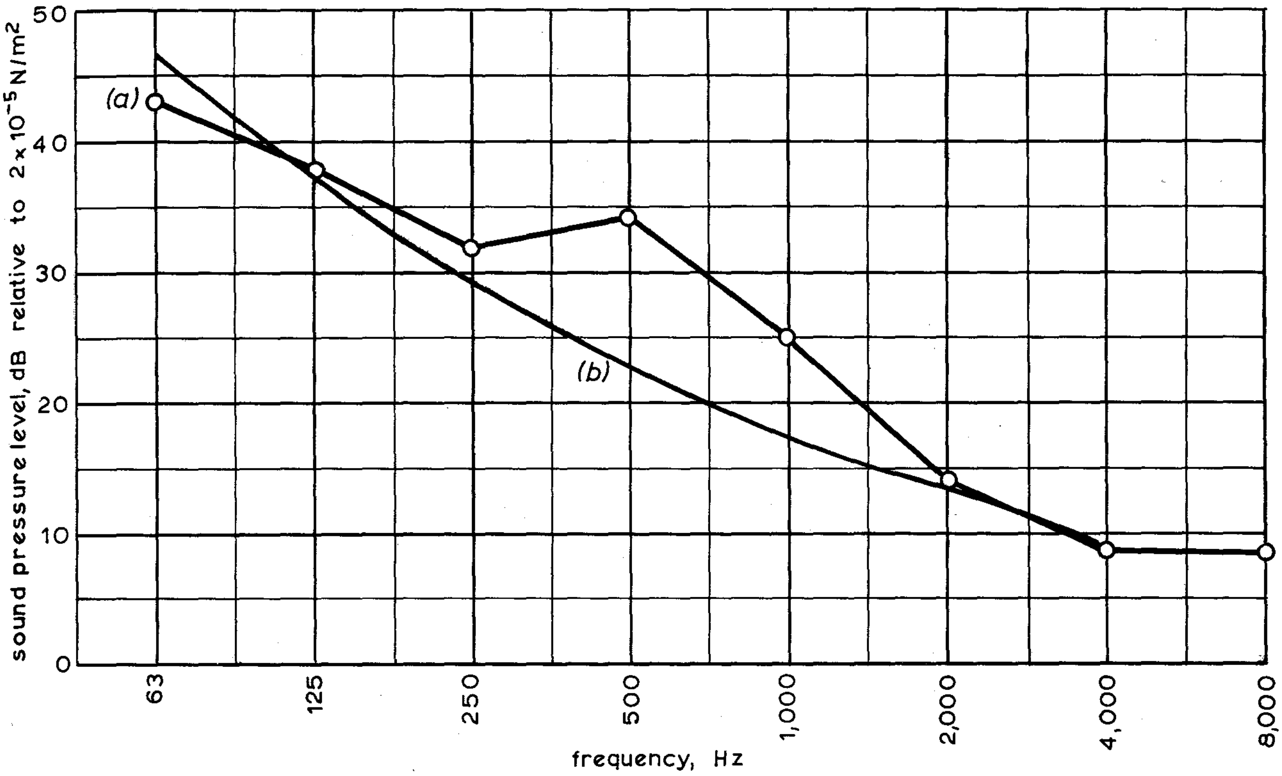


Fig. 12 Noise levels in Studio 2.

(a) Measured noise levels. *(b)* Criterion

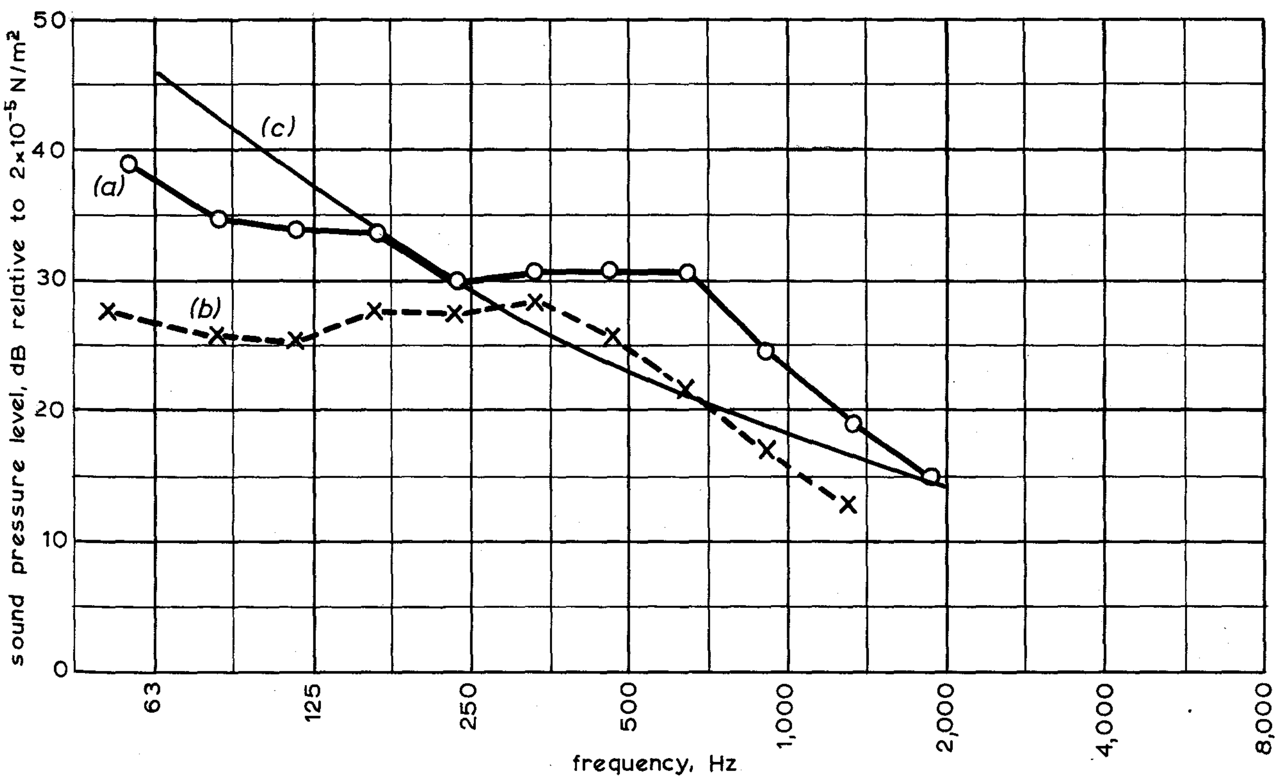


Fig. 13 Provisional noise levels in Studio 2 Suite.

(a) Recording Room of Studio 2 *(b)* Control Cubicle of Studio 2. *(c)* Criterion.

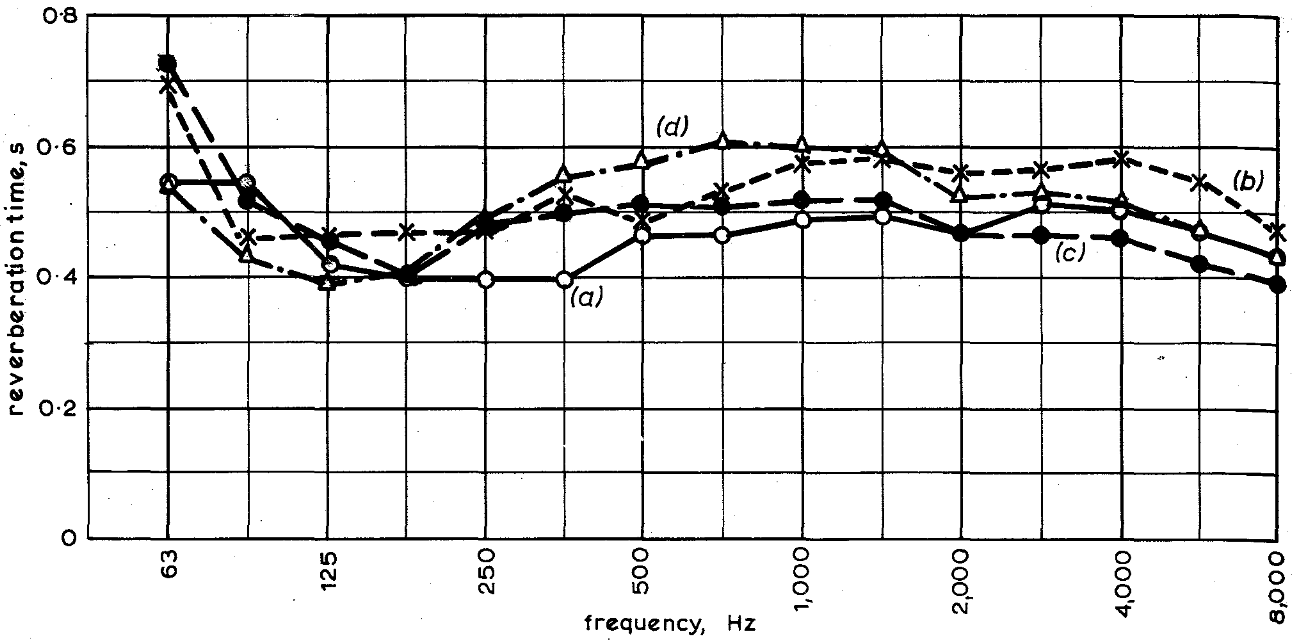


Fig. 14 Reverberation times in Studio 3 areas.

(a) Narrator's Studio. *(b)* Studio 3.
(c) Control Cubicle 3. *(d)* Recording Room 3.

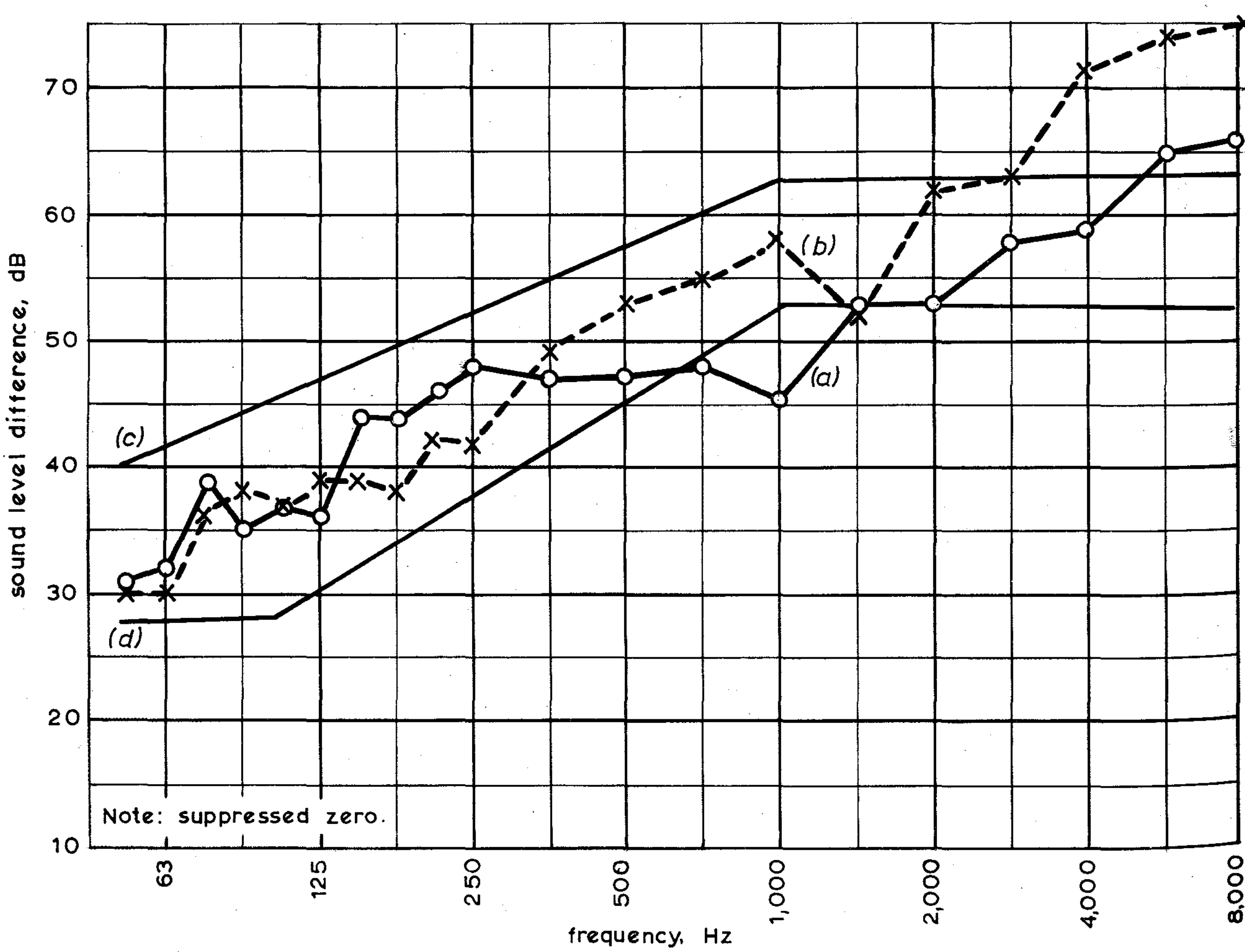


Fig. 15 Sound level differences.

(a) Studio 3 to Recording Room (criterion *(c)* applies.)

(b) Studio 3 to Cubicle (criterion *(d)* applies.)

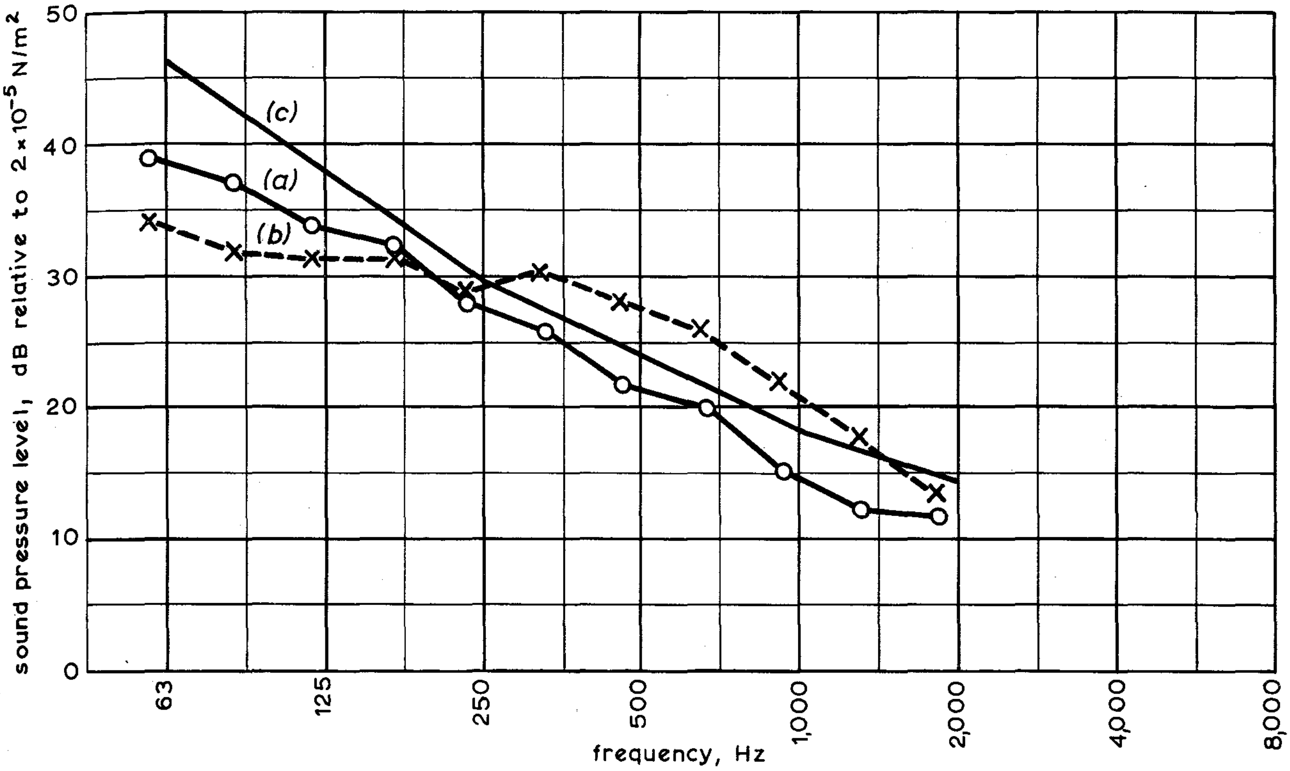


Fig. 16 Provisional noise levels in Studio 3.

(a) Narrator's Studio. *(b)* Studio 3. *(c)* Criterion.

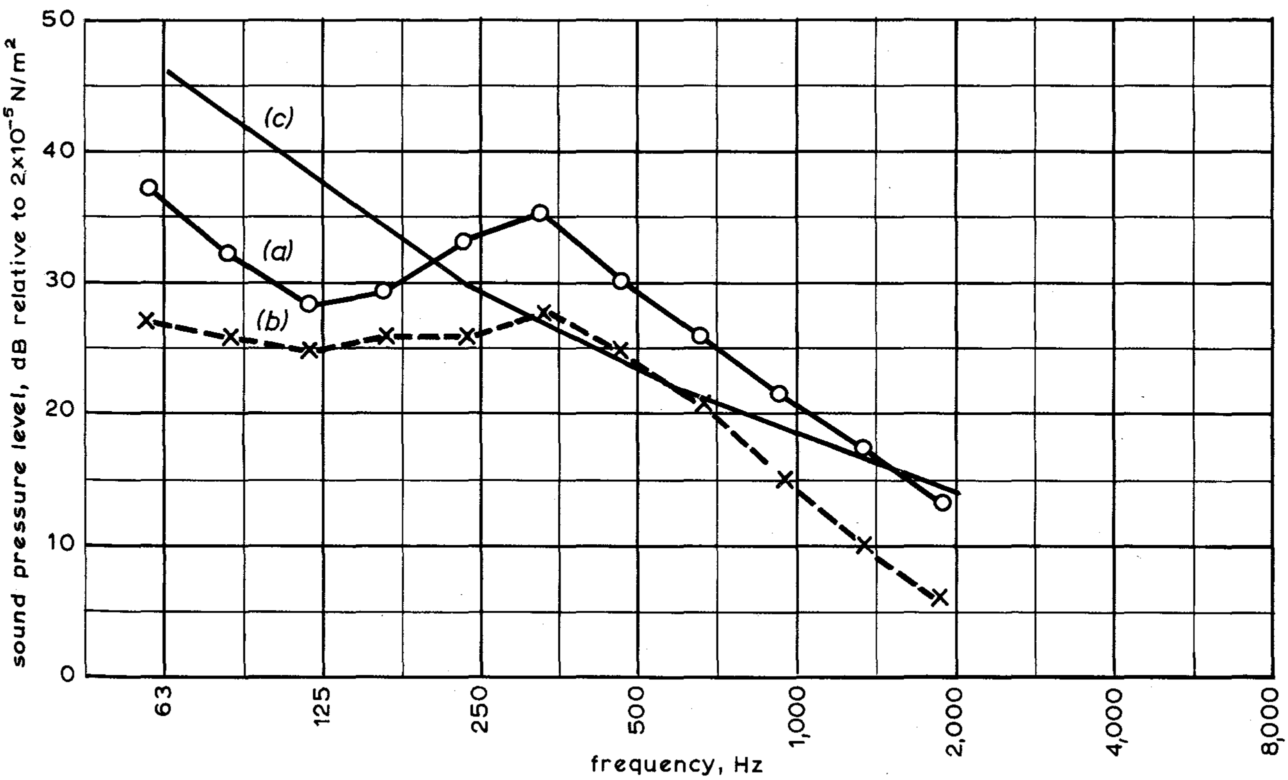


Fig. 17 Provisional noise levels in Studio 3 Suite.

(a) Recording Room of Studio 3. *(b)* Control Cubicle 3. *(c)* Criterion.

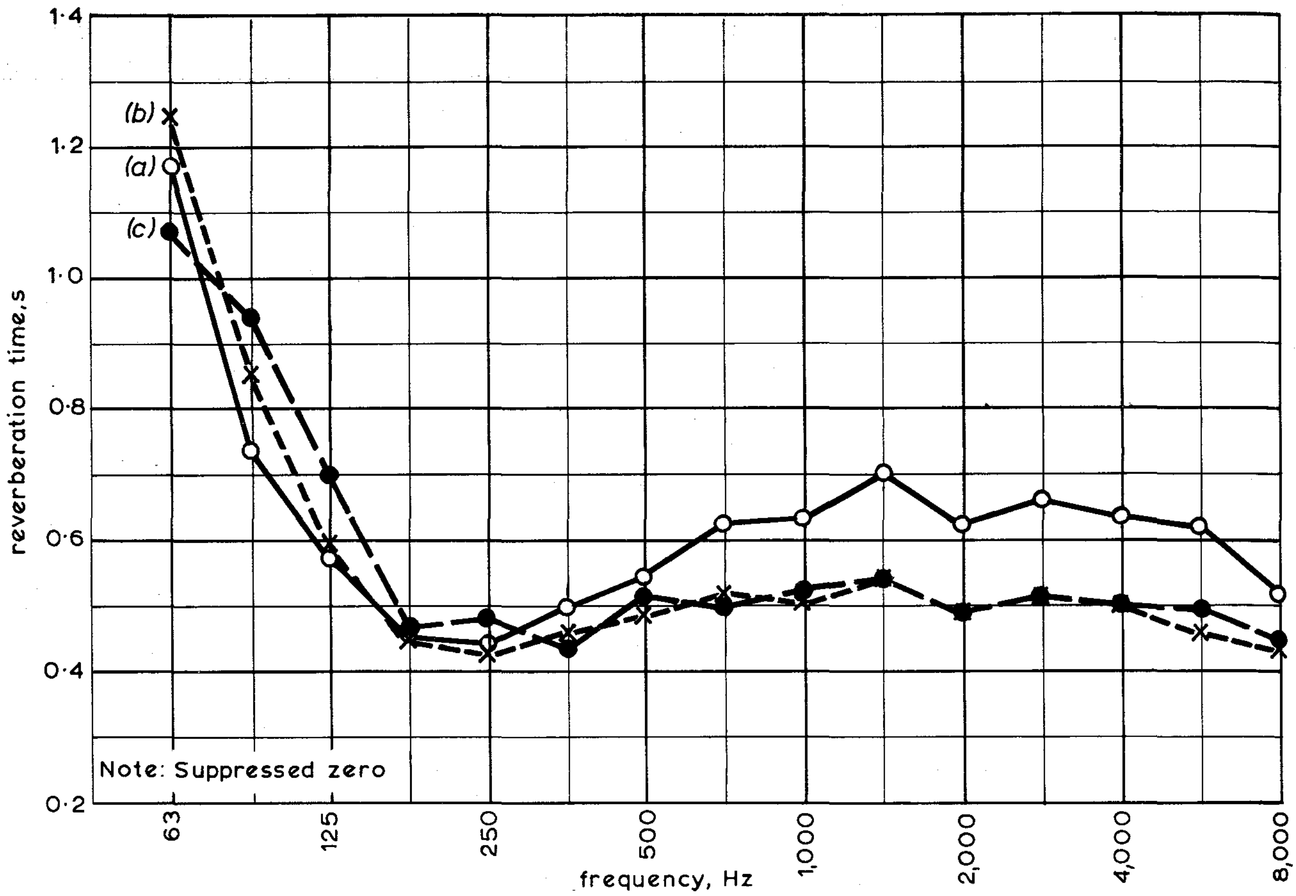


Fig. 18 Reverberation times in Studios 4,5 and 6.

(a) Studio 4 *(b)* Studio 5 *(c)* Studio 6

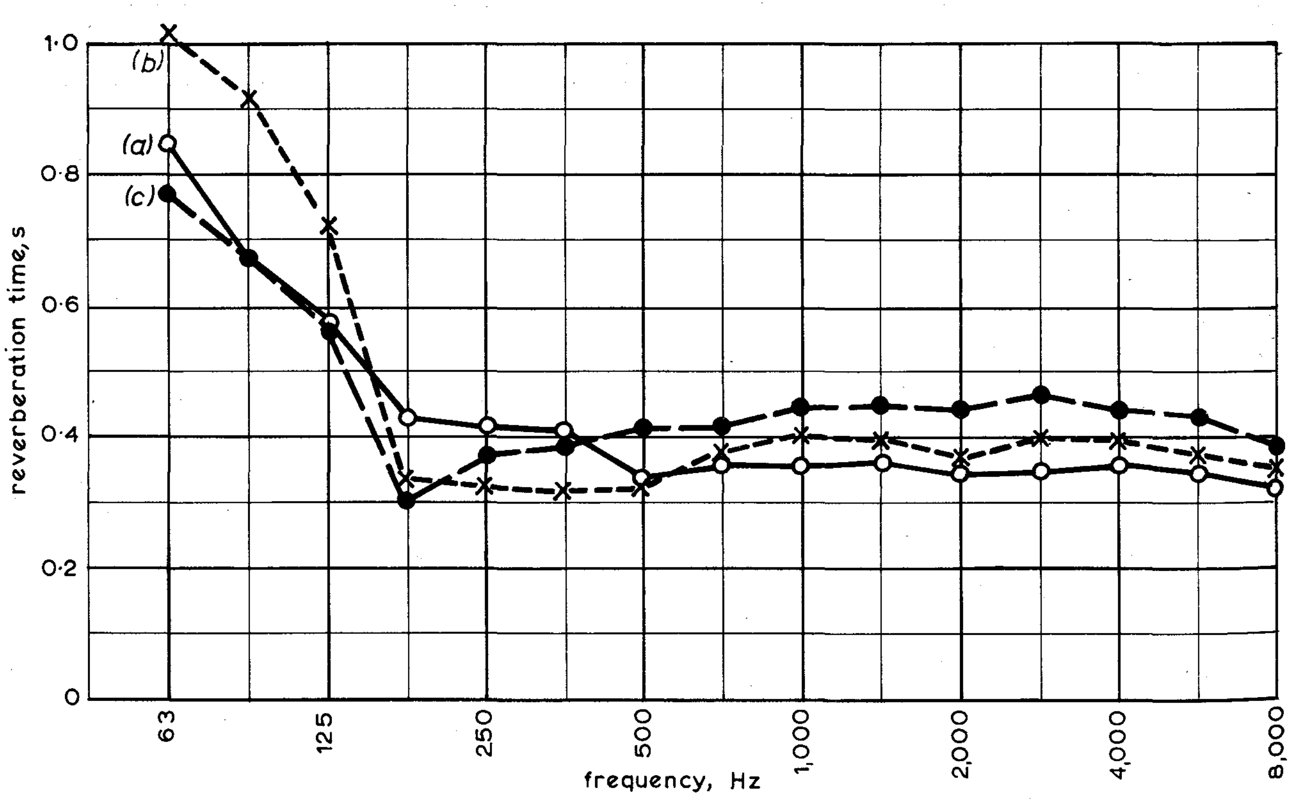


Fig. 19 Reverberation times in Cubicles 4,5 and 6.

(a) Cubicle 4 *(b)* Cubicle 5 *(c)* Cubicle 6.

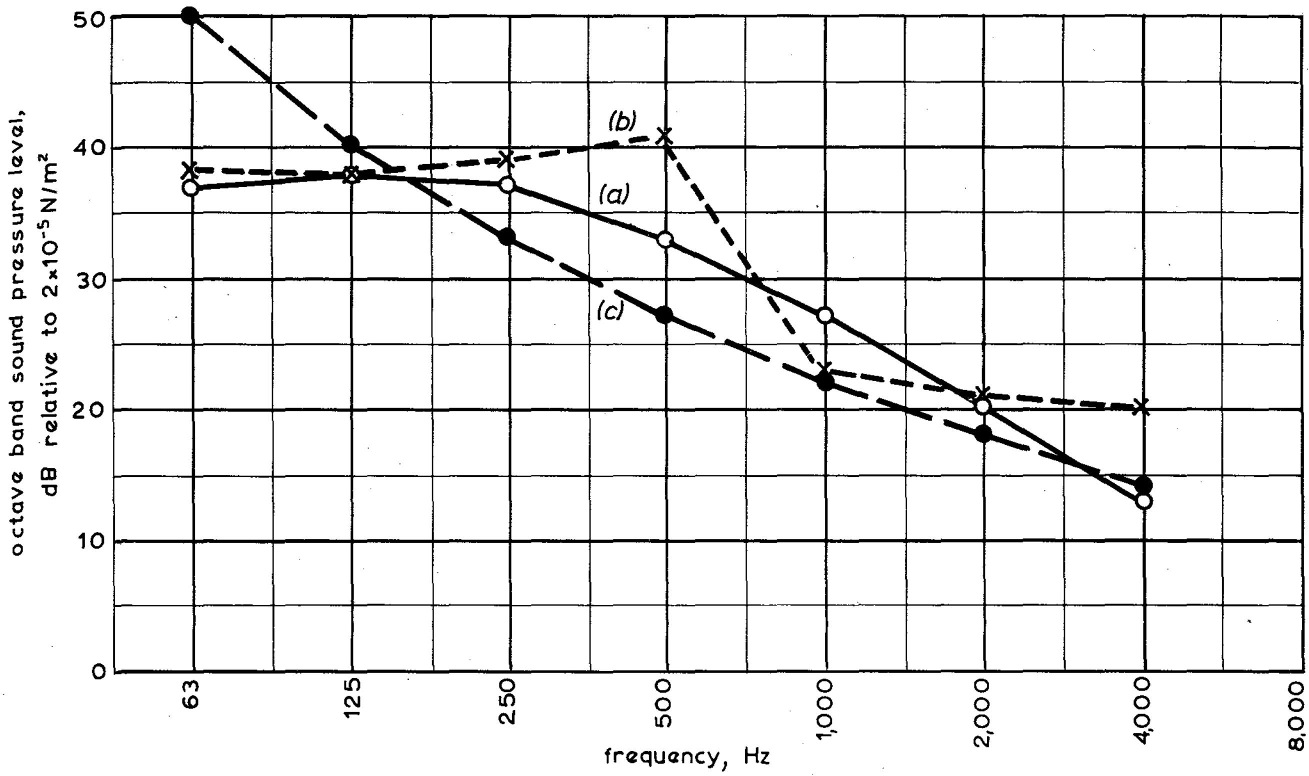


Fig. 20 Noise levels in Studio 4 Suite.

(a) Studio 4 (b) Cubicle 4 (c) Permissible noise levels

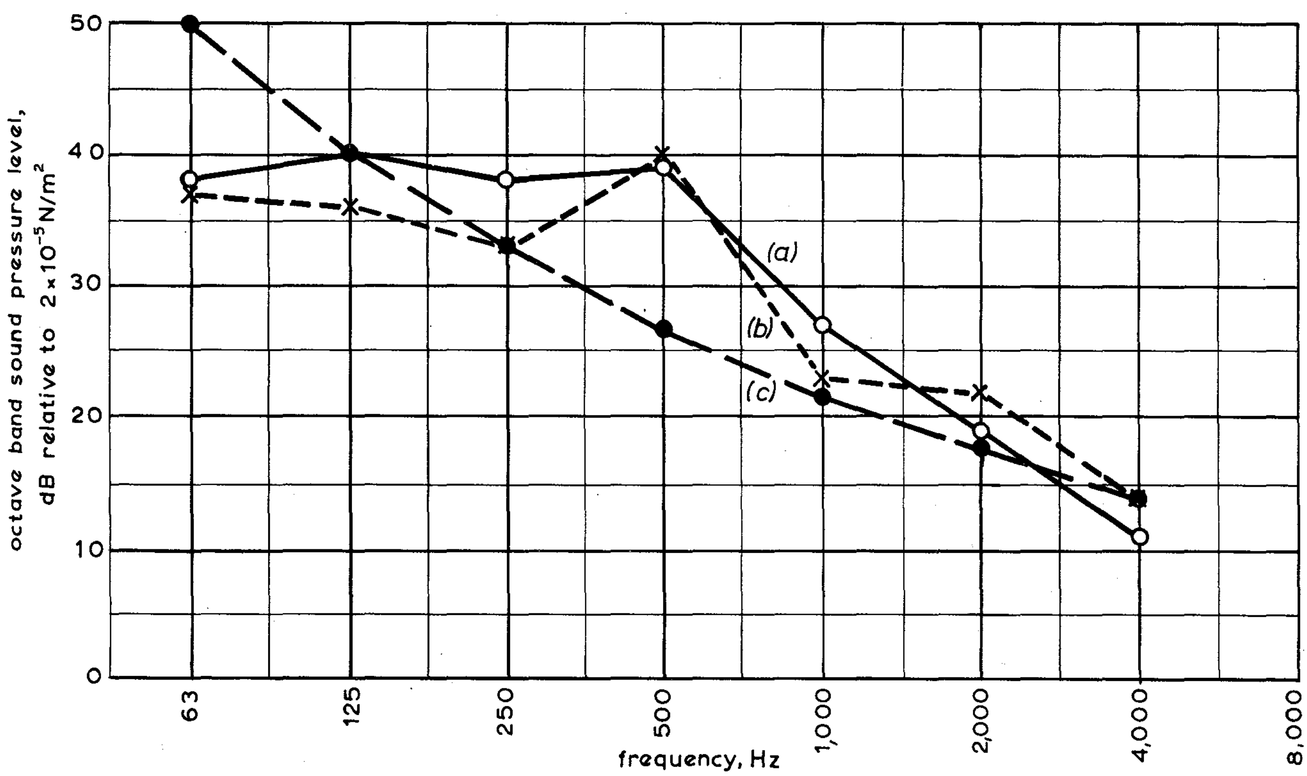


Fig. 21 Noise levels in Studio 5 Suite

(a) Studio 5 (b) Cubicle 5 (c) Permissible noise levels.

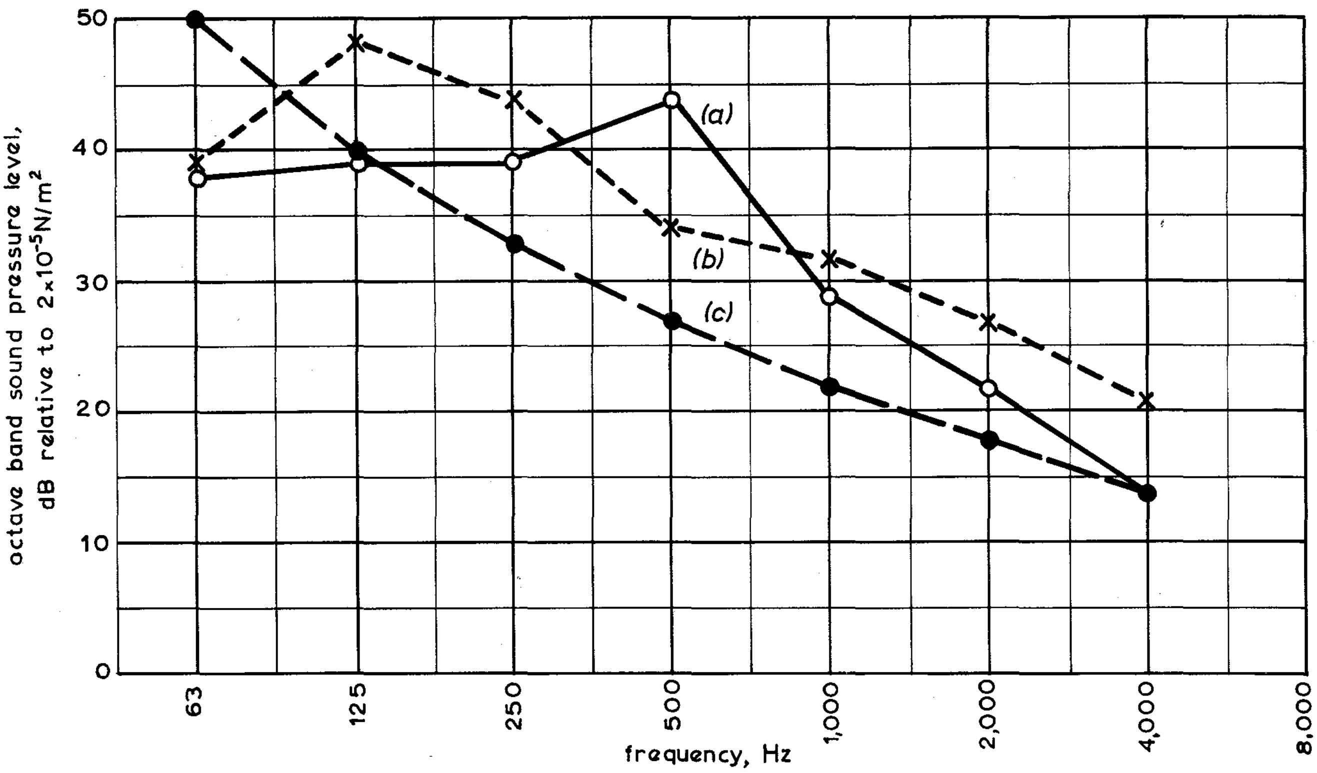


Fig. 22 Noise levels in Studio 6 Suite.

(a) Studio 6 *(b)* Cubicle 6 *(c)* Permissible noise levels.

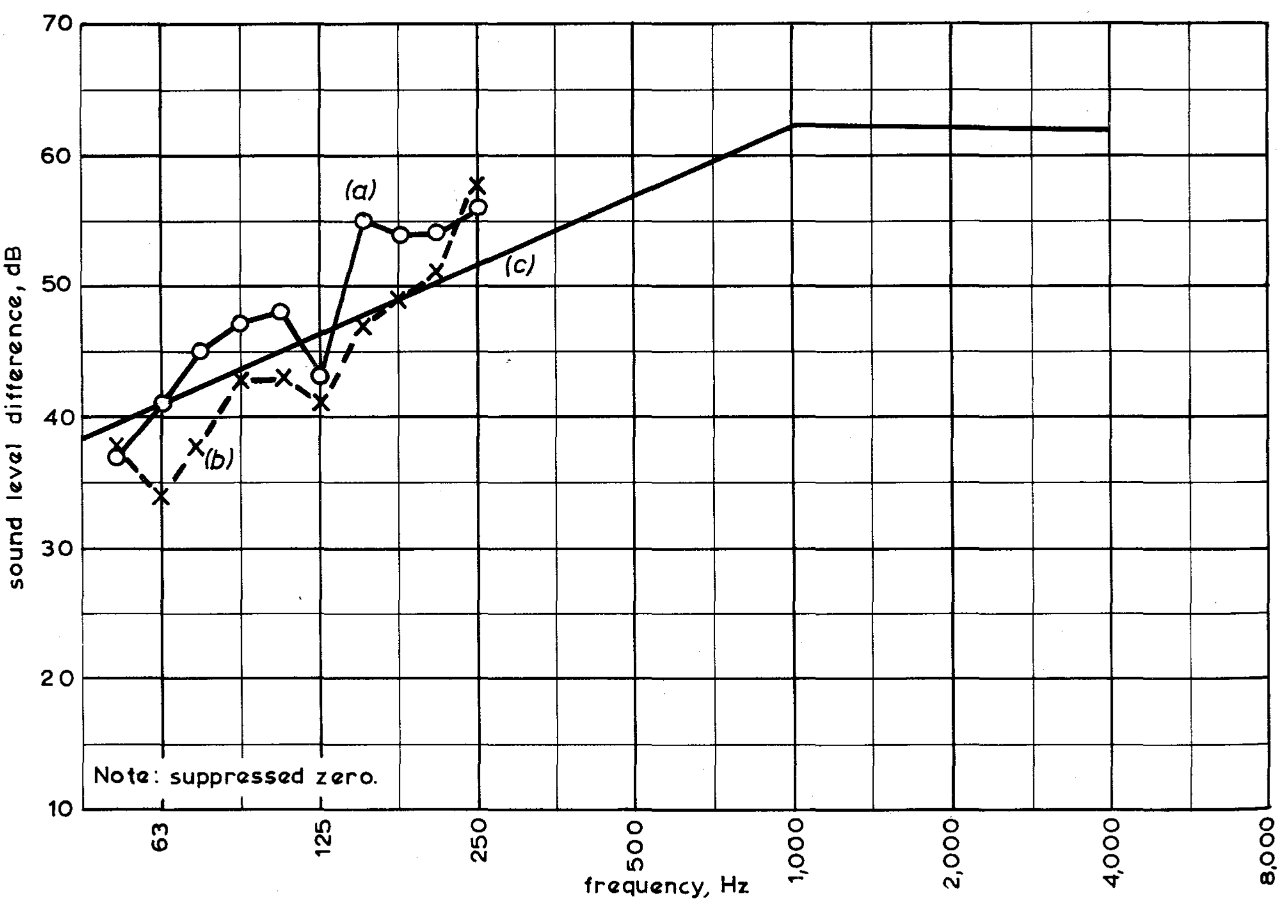


Fig. 23 Sound insulation in Suites 4, 5 and 6.

(a) Studio 6 to Cubicle 5 *(b)* Studio 5 to Cubicle 4 *(c)* Criterion

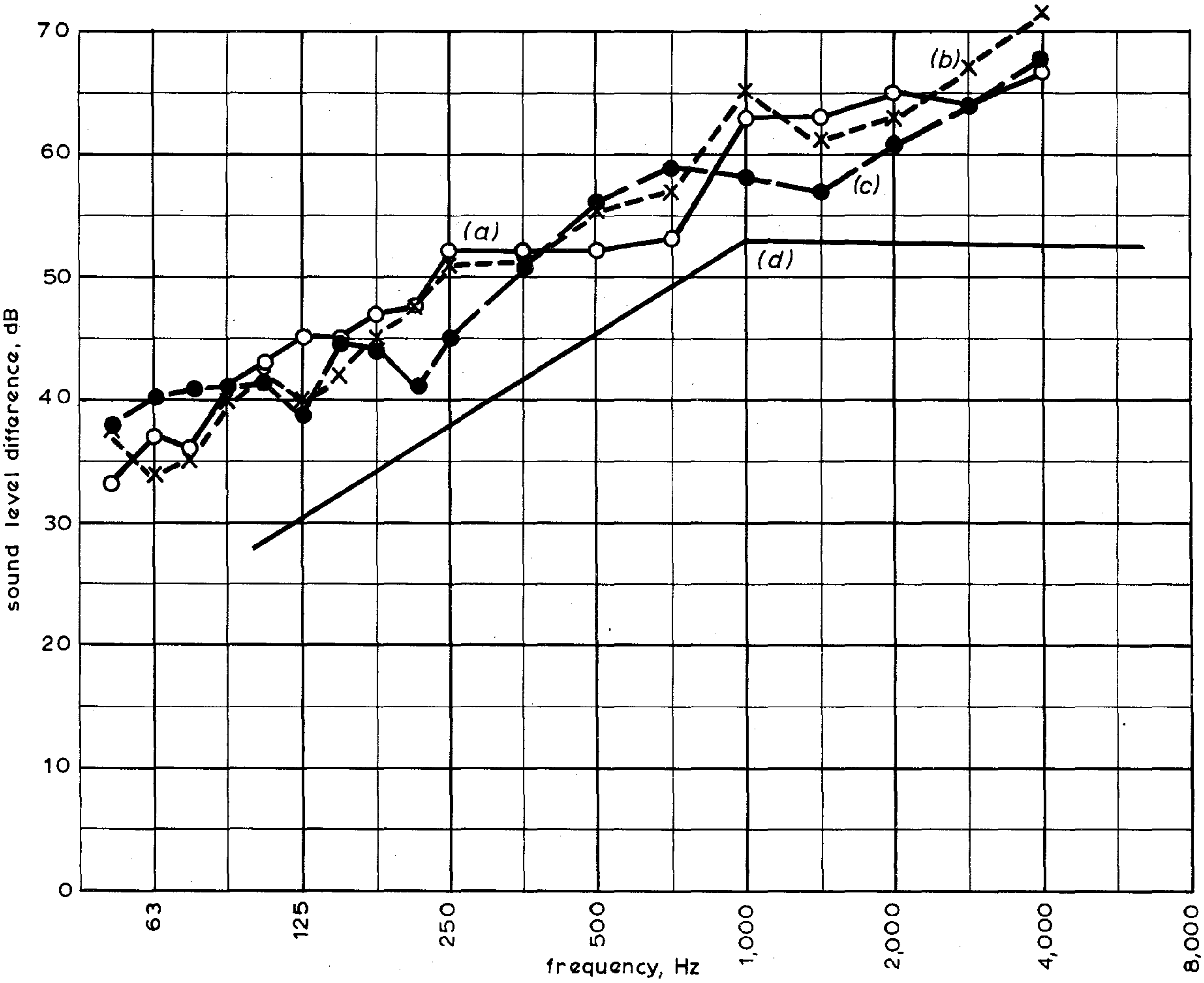


Fig. 24 Sound insulation in Suites 4,5 and 6. (cont'd)

(a) Studio 4 to Cubicle 4.
(b) Studio 5 to Cubicle 5
(c) Studio 6 to Cubicle 6.
(d) Criterion.